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REPORT R-1613

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FRANKFORD ARSENAL

DEVELOPMENT AND ENGINEERING TEST OF

NEW COOL BURNING EXTRUDED AND ROLLED

BALL TYPE PROPELLANTS FOR

20MM AIRCRAFT AMMUNITION

by

A. Victor Nardi

REPORT R-1613

February 1962

This report contains a Code Sheet

PHILADELPHIA 37, PA.

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DEVELOPMENT AND ENGINEERING TEST OF NEW COOL BURNING EXTRUDED AND ROLLED BALL TYPE PROPELLANTS FOR 20MM AIRCRAFT AMMUNITION

OMS Code

DA Project 504-05-029

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February 1962

This report contains a Code Sheet

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INTRODUCTION

Contractor A successfully developed, under the direction of Frankford Arsenal, a cool burning, single base extruded propellant CR 7695 for use in 20mm aircraft ammunition. Frankford Arsenal Reports R-1449 and R-1470¹, ^{2*} describe the development and tests of this propellant CR 7695 and the various other single base extruded propellants that led up to its development. Following this development an attempt was made to improve the erosion characteristics of single base extruded propellant by two methods; namely, (a) obtaining a centralite coated propellant that develops a lower chamber pressure than CR 7695 when fired and (b) developing a new small arms extruded single base cool burning propellant type with a deterrent incorporated in the base grain.

Contractor A continued the developments under existing contract DA-36-034-507 ORD 125RD. 3

These two new propellants were designated CR 7787 (the centralite coated propellant) and CR 7814 (the internally deterred and centralite coated propellant). A new rolled ball propellant designated X 2048 had also been developed by Contractor B for 20mm ammunition. After satisfactory preliminary testing at Frankford Arsenal, combined engineering and erosion tests were fired at Aberdeen Proving Ground with these three propellants.

The details of the development of the extruded propellants CR 7787 and CR 7814 together with the results of the engineering and erosion tests at Aberdeen Proving Ground with these extruded propellants and rolled ball propellant X2048 are reported herein. Data has been previously reported to the customer by letter. 8

METHOD

Development of Extruded Propellants

Contractor A, technically supervised by Frankford Arsenal, was to develop cool burning extruded propellants that would be suitable for

.

^{*}See References

use in 20mm aircraft ammunition. The first two phases of the development have been reported. ^{1,2} This report covers the third phase of the propellant development. The contractor, after consultation with representatives of Frankford Arsenal, prepared small (2 to 5 lb.) samples of propellant for testing. Initial tests (including closed bomb firings) were performed at the contractor's laboratory. When these tests indicated the propellants to be ballistically suitable, samples were forwarded to Frankford Arsenal for ballistic testing in Cartridge, Ball, 20mm, M55 at +70° F. After a review of the results of the ballistic tests of all the samples submitted to Frankford Arsenal, the two most satisfactory propellants were selected and larger samples were manufactured and subjected to more extensive tests at +70°, -70° and +165° F. Propellant CR 7695 developed under the second phase of this propellant development² was used as a control in these tests.

Engineering and Erosion Tests at Aberdeen Proving Ground with Experimental Propellants and Primer

Since the development of experimental double-base rolled ball propellant X2048 was completed about the same time as the development of extruded single base experimental-propellants CR 7787 and CR 7814, it was decided to combine the engineering and erosion tests of all three propellants at Aberdeen Proving Ground.

Since the development of the FAT 27E1 primer had also been completed⁵ it was decided to load all the new propellants into cases primed with the FAT 27E1 primer. Therefore, these tests would also serve as engineering and erosion tests of the new primer. Additionally, these tests became an evaluation of ignition systems rather than evaluations of specific propellant or primer types.

The first four of the following listed lots of Cartridges, Ball, 20mm, M55 type were loaded at Frankford Arsenal and forwarded to Aberdeen Proving Ground for test. The fifth lot was supplied by Aberdeen Proving Ground as a control and contained the standard WC 870 propellant and M52A3B1 primer.

Lot No.	Propellant	Primer	Quantity
FA-X20-2767	CR7695 Lot 3	FAT27E1	12,000
FA-X20-2768	CR7787 Lot 4	FAT27E1	12,000
FA-X20-2769	CR7814 Lot 2	FAT27E1	12,000
FA-X20-2770	X2048	FAT27E1	10,000*
KOP 153-18	WC870AL40378	M52A3B1	-

^{*}NOTE - Only 10,000 rounds of lot FA-X20-2770 were loaded at this time because it was desired to hold the remaining quantity of propellant X2048 for other possible ballistic tests. An additional quantity of approximately 3500 rounds was shipped to APG at a later date.

All five lots of 20mm ammunition were subjected to the following test program at Aberdeen Proving Ground.

	Total Rounds to be Tested Per Lot Per Test								
Test	Fired at +70° F	Fired at -70° F	Fired at +165° F	Total Rds. Per Lot					
Pressure, Velocity and Action Time (Gage)	20	20	20	60					
Velocity (M39 Ma- chine Gun)	20	20	20	60					

Erosion (M39 Machine Gun) (See Narrative Below)

The erosion test was fired in the M39 machine gun using a schedule of 125-round bursts with 30-second cooling between bursts and complete cooling after every 250 rounds. A barrel was disqualified when (a) the average velocity of any 20 consecutive cartridges of a burst was 6% or more below the average velocity of the first 20 round burst fired in the

new barrel; or (b) yaw of 15 degrees or more is encountered with 20 percent or more of any consecutive 40 rounds of any burst. Five barrells were to be fired to completion with each lot of ammunition if sufficient rounds were available.

DISCUSSION OF RESULTS

Development of Extruded Propellants

The quarterly reports and the final report submitted by Contractor A³ give a detailed account of the progress of the 20mm extruded propellant development. During the entire period of the development, the contractor prepared and tested at his laboratory approximately 350 experimental 20mm propellants. The twenty different basic compositions utilized are listed in the contractor's final report. Those samples that were found to be ballistically suitable for 20mm ammunition by closed bomb firings and limited ballistic testing at the contractor's laboratory were submitted to Frankford Arsenal for ballistic testing in Cartridge, Ball, 20mm, M55. During this phase of the propellant development, 24 such preliminary samples were found suitable at the contractor's laboratory and were submitted to Frankford Arsenal. Table I lists the identity, composition, granulation, flame temperature and the initial ballistic performance at Frankford Arsenal of these samples. It should be noted that in some instances propellant samples with the same composition and granulation gave vastly different ballistics. This is because the compositions listed are nominal and do not reflect the actual propellant composition. These samples were produced in the contractor's semi-works and were 2 to 5 lbs, with the result that they were generally exhausted in ballistic testing so that chemical analysis could not be made. Such a chemical analysis would have probably indicated large differences in the amount of deterrent actually present in the samples.

After reviewing the results listed in Table I, it was concluded that propellant Ex7787* gave the most satisfactory ballistic results of the

^{*}It might be well to note at this point that the contractor identifies his experimental propellant samples with Ex numbers. However, if a sample type leads to an acceptable propellant type, the Ex is changed to CR (Cool Rifle). Therefore, propellants Ex 7787 and 7814 will be later identified as Cr 7787 and 7814.

Table No. I

Table Showing Identity, Composition, Granulation, Calculated Flame Temperature and Ballistic Performance of Various, Single Base, Entruded, Experimental Propellants When Tested in Cartridge, 20mm, Ball, MS5. Ballistic Requirements; 3380 à 50 f/s Within a Maximum Average Pressure of 58,000 pel With An Action Time Not To Encode 3,5 m. s. When Fired in A Pressure Gage

						Gage Firing		
Propolisat Designation	Propellant Composition and Granulation (Nominal in Parts)	Calculated Flame Temp. *K	Propellant Charge grs	Primer	Action Time	Short Piston Vol. f. s.	Pressure pei	Remarks
Ex7756	100 Nitrocellulose; 1 DPA; 1 K ₂ 80 ₄ ; 1 Tin Cotted 6 DNT and 5 DBP; 0.056" - 0.15" x 1/16"	2510	560 (full ease)	M52A3B1	5, 52	3272	48200	Unsuitable, Low Velocity and High action time
<u>21</u> 1757	100 Nitrocelluless; 1 DPA; 1 K ₂ Sa ₆ ; 1 Tin Cested 6 DNT and 4 DBP; 0, 060" - 0, 015" x 1/16"	2590	Sé8 (full case)	MSSASBI	4, 74	3321	48700	Unsuitable, Low Velocity and High action time
Ex7758	96 Nitrecullulace; 2 DBP; 2 K ₂ 80 ₆ ; 1 DPA; 1 Tin Cented 6 Cent. No. 2 0, 070" - 0, 015" x 1/16"	2450	575 (full case)	MS2A3B1	2, 63	3360	53500	Satisfactory, contractor will supply additional sample
Ex7759	100 Nitrocullulose; 2,5 DBP; 1 DPA; 1 R ₂ 50 ₄ ; 1 Tin Cented 7 Cent. No. 2 0, 660" - 0, 015" x 1/16"	2340	555 (full case)	M52A3B1	4. 05	3315	51900	Unsuitable, Low Velocity and High action time
Ex7764	98 Nitrocellalose; 2 DBP; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Conted 5-1/2 Cent. No. 2 0.070" - 0.015" x 1/16"	2485	560 (full case)	M52A3B1	3, 15	3201	46400	Unsuitable, Low Velocity Sample not ballistically similar to Ex7758 contractor will make new . sample
Ex7760	100 Nitrocellalose; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Cented 8 Cent. No. 2 0. 065" - 0. 015" x 1/16"	2470	550 (full case)	M52A3B1	2. 99	3340	56 900	Unsuitable, Low Velocity
Ex7763	100 Nitrecellalose; 2 Kg804: 1 DPA; 1 Tin Cented & Cent. No. 2 0. 975" - 0. 015" x 1/16"	2600	570 (full case)	M52A3B1	2.76	3397	54800	Maybe suitable, contractor will make additional sample
Ex7761	100 Nitrecellulose; 2 R ₂ 80 ₄ ; 1 DPA; 1 Tin; 15 DNT Double Conted 0.070" - 0.015" x '/16"	•	\$68 (full case)	M52A3B1	3, 27	3314	51400	Unsuitable, Low Velocity
2 ≘7762	100 Nitrocellaiose; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Cested 7.5 DNT and 4.0 Cent. No. 2 0.065" - 0.015" x 1/16"	-	560 (full case)	M52A3B1	2. 98	3365	60780	Unsuitable, High Pressure
Ex7786	100 Nitrecellulose; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin; Deable Coated 6 Cont. No. 2 and 4 DNT 0.070" - 0.015" x 1/16"	-	578	M52A3B1	3, 19	3416	55400	Unsuitable, High action time
Ex7787	100 Nitreculinises; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Costed 6 Cent, No. 2 0, 075" - 0, 015" x 1/16"	2610	570	M52A3B1	2. 94	3384	53700	Satisfactory, contractor will supply additional sample
Ex7788	100 Nitroculmiose; 2 K ₂ 60 ₄ ; 1 DPA; 1 Tin Coated 5 Cent. No. 2 0.075" - 0.015" x 1/16"	2600	570	M52A3B1	3, 00	3419	56200	Unsuitable, action time high

NoTE: Abbreviations

DPA: Diphenylamine K₂804: Potassium Sulfate DBP: Dibutyl Phthalate

Table No. I (Cont'd)

	Propeliant Composition	Calculated	Propellant			Gage Firing		
Propellant Designation	and Granulation (Nominal in Parts)	Flame Temp,	Charge	Primer	Action Time me	Vel, f. s.	Pressure pei	Remarks
Ex?789	98 Nitrocallulese; 2 DBP; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tim Coated 4 Cent. No. 2 0.070" - 0.015" x 1/16"	2590	587 (full case)	M52A3B1	3, 17	3289	45100	Unsuitable, Low Velocity
Ex7790	96 Nitrocellulose; 2 DBP; 2 K ₂ 50 ₄ ; 1 DPA; 1 Tim Costed 6 Cent. No. 2 0.070" - 0.015" x 1/16"	2450	580 (full case)	M52A3B1	3. 69	3023	32000	Unsuitable, Low Velocity High action time
Ex7796	Not available	• .	565	M52A3B1	3.03	3330	514000	Unsuitable, Low Velocity
Ex7802	98 Nitrocellulose; 2 DBP; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Coated 6 Cent. No. 2	2450	580 (full case)	M52A3B1	· •	3183	45500	Unsuitable, Low Velocity
••	0. 070" - 0. 015" x 1/16"		• .	FAT36E7 Lot H	2, 87	3220	47300	
Ex7803	98 Nitrocellulose; 2 DSP; 2 K ₂ 50 ₄ ; 1 DPA; 1 Tin Coated 6 Cent, No. 2	2450	580 (full case)	M52A3B1	Í1, 65	3048	37100	Unsuitable, Low Velocity
	0, 070" - 0. 015" x 1/16"			FAT36E7 Lot H	3, 28	3139	39700	
Ex7804	98 Nitrocellulose; 2 DBP; 2 K ₂ S0 ₄ ; 1 DPA; 1 Tin Coated 5 Cent. No. 2	2520	585 (full case)	M52A3B1	2, 95	3284	46100	Unsuitable, Low Velocity
•	0,070" - 0.015" x 1/16"			FAT36E7 Lot H	2, 75	3312	51400	
Ex7810	98 Nitrocellulose, 2 DRP; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Costed 4 Cent. No. 2 0.070" - 0.015" x 1/16"	·	585 (full case)	M52A3B1	• •	3403	57900	Satisfactory, However Pressure High
Ex7611	98 Nitrocellulose; 2 DBP; 2 K ₂ \$0 ₄ ; 1 DPA; 1 Tin Coated 5 Cent. No. 2		585 (full case)	M52A3B1	2.79	3384	57200	Satisfactory, However Pressure High
	0, 070" - 0, 015" x 1/16"	٠.						
Ex7612	98 Nitrocellulose; 2 DBP; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Conted 4 Cent, No. 2 0,070" - 0,015" x 1/16"	; .·	585 (full case)	M52A3B1	3, 21	. 3273	45500	Unsuitable, Low Velocity
Ex7813	98 Nitrocellulose; 2 DBP; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Coated 5 Cent. No. 2 0,070" - 0,015" x 1/16"	-	585 (full case)	M52A3B1	3, 29	3177	40400	Unsuitable, Low Velocity
Ex7814	98 Nitrocellulose; 2 DBP; 2 K ₂ 80 ₄ ; 1 DPA; 1 Tin Coated 4 Cent. No. 2	2580	585 (full case)	M52A3B1	2. 87	3350	50500	Satisfactory
Ex7815	0.070" - 0.015" x 1/16" 98 Nitrocellulose, 2 DBP; 2 K2804; 1 DPA; 1 Tin Coated 4.5 Cent. No. 2 0.070" - 0.015" x 1/16"	-	585 (full case)	M52A3B1	3. 01	3289	47400	Unsuitable, Low Velocity

NOTE: Abbreviations

DPA: Diphenylamine
K₂80₄: Potassium Sulfate
DBP: Dibutyl Phthalate

centralite coated samples, while the Ex7814 propellant gave the best ballistics of the internally deterred and coated samples. Accordingly, additional samples of propellants Ex7787 and Ex7814 were obtained from Contractor A for a temperature coefficient test in Cartridge, Ball, 20 mm, M55. Since the Ex7787 propellant gave a much better ballistic relationship with the newly developed FAT 27E1 primer **than with the standard M52A3B1 primer, the new primer was used with this propellant while the standard primer was used with the Ex7814 propellant and with the control ammunition which was loaded with CR7695 propellant.

The results of the tests fired at +70°, -70° and +165° F are given in Table II. These results show that propellant Ex7787 with FAT 27E1 primer gave the best results with a spread of only 103 feet in mean velocity over the temperature range of -70° to +165° F. The other two experimental single base propellants (CR7695 and Ex7814 both with M52A3B1 primers) also gave good results, the spread in velocity being 162 feet and 184 feet respectively. It should be noted the normal spread over the temperature range with the standard ammunition loaded with ball WC870 propellant with M52A3B1 primers is between 250 and 350 feet per second.

Since both experimental propellants (Ex7787 and Ex7814) appeared to have temperature coefficients better than the standard propellant (WC870), it was decided to procure a sufficient quantity of both propellants from Contractor A in order that ammunition could be loaded and engineering and erosion tests fired at Aberdeen Proving Ground. A quantity of propellant CR7695 was also ordered from this contractor to be loaded into control ammunition for these tests.

Engineering and Erosion Tests at Aberdeen Proving Ground with Experimental Propellants and Primers

1. Ballistic Tests

Table III gives the results of the ballistic tests fired in the gage and the M39 machine gun at $+70^{\circ}$, -70° and $+165^{\circ}$ F.

^{**}FAT 27E1 Primer is FAT 36E7 Primer with modified hardware (see ref. 5).

TABLE II

Table of Ballistic Data Showing Results after Storage for a Minimum of 2 Hours at the Required Temperature
All firings in Gage with Cartridge Ball, 20 mm, M55

Propellant Ex7814, Charge 585 grs, Primer M52A3B1

Temp F	Action Time	Velocity f/s	SD f/s	Pressure psi	SD psi	
70	2.86	3367	12	53100	1500	
-70	3.12	~3252	19	46700	1600	
+165	2.82	3436	12	58000	1600	

Temperature Coefficient (-70° to +165° F) = 0.78 $f/s/^{\circ}F$

Propellant Ex7787-1, Charge 570 grs, Primer FAT36E7 (Now FAT27E1 Type)

Temp °F of Firing	Action Time ms	Velocity f/s	SD f/s	Pressure psi	SD psi	
70	2.72	3370	13	52900	1500	
-70	2.92	3300	37	51000	3400	
+165	2.73	3403	19	54100	2100	

Temperature Coefficient (-70° to +165° F) = $0.44 \text{ f/s/}^{\circ}\text{F}$

Propellant CR7695-1, Charge 566 grs, Primer M52A3B1

Temp°F of Firing	Action Time ms	Velocity f/s	SD f/s	Pressure psi	SD psi	
70	2.75	3390	12	56100	2300	
-70	3.05	3281	28	49800	3000	
+165	2.69	3443	15	58100	2400	

Temperature Coefficient (-70° to +165° F) = $0.69 \text{ f/s/}^{\circ}\text{F}$

TABLE No. III

Results of Ballistic Tests at +70°, -70° and +165° F

Lot FA 2767 CR7695 Lot 3; Propellant Charge 555 grs; Primer FAT 27E1

										Acceptance
	Machine		Action		8. P.	Gage			8. P.	
Temp. °F	Velocity	\$D	Time	E. V.	Velocity	SD	Pressure	8D	Velocity	Pressure
of Firing	1. s.	1, 0,	m. s.	m. s.	1. 0.	1. 0.	pei	pei	1. 0.	<u>pei</u>
+70	3212	19	2, 53	0. 22	3327	18	57900	2200	3350	57800
-70	3167	25	2, 72	0, 25	3308	13	60500	2500		
+165	3264	14	2. 55	0.13	3345	7	58200	1700		

Lot FA 2768

CR7787 Lot 4; Propellant Charge 578 grs; Primer FAT 27E1

Machine Gun			Action	•	8. P.	Gage			F. A. Gage Acceptance S. P.		
Temp. 'F of Firing	Velocity f. s.	8D 1. s.	Time m. s.	E. V. m. s.	Velocity f. s.	8D f. e.	Pressure pei	SD psi	Velocity f. s.	Pressure psi	
+70	3198	25	2, 73	0.12	3354	. 13	53800	1400	3383	55300	
-70	3079	37	2. 98	0.34	3269	22	48700	2800		•	
+165	3238	12	2.74	0. 11	3373	14	57100	1400			

Lot FA 2769

CR7814 Lot 2; Propellant Charge 573 grs; Primer FAT 27E1

Machine Gun			Action		S. P.	Gage			F. A. Gage Acceptance S. P.		
Temp. 'F of Firing	Velocity f. s.	5D 1. s.	Time m. s.	E, V. m. s.	Velocity f. s.	5D	Pressure pai	SD pei	Velocity f. s.	Pressure psi	
+70	3219	22	2, 72	0. 13	3357	9	54200	1400	3378	54800	
-70	3109	32	2, 95	0. 30	3269	17	49600	2000			
+165	3245	14	2.72	0. 08	3364	6	56200	1000		. ••	

Lot FA 2770

X2048; Propellant Charge 588grs; Primer FAT 27E1

		_							F.A. Gage Acceptance			
Temp, 'F	Machine Velocity	Gun SD	Action Time	E. V.	S, P, Velocity	Gage SD	Pressure	SD	S. P. Velocity	Pressure .		
of Firing	1. s.	1.0.	m. s.	m. s.	f. s.	1. 0.	pei	psi	f. s.	psi .		
+70	3179	26	2. 93	0. 18	3317	12	54100	1300	3357	54200		
-70	3088	18	3, 02	0.37	3236	23	56600	2500		•		
+165	3164	32	2. 93	0, 27	3281	22	50700	1800		-		

Lot KOP 153-18

(Badger) WC 870 AL 40378; Propellant Charge, Primer M52A3B1

	Machine	Gun	Action		S. P.	Gage		
Temp. *F	Velocity f. e.	SD f. s.	Time m. s.	E. V. m. s.	Velocity f. s.	SD 1. ●.	Pressure psi	SD pei
+70	3284	30	2, 55	0. 09	3362	12	50000	1000
-70	3047	22	2. 78	0.19	3215	33	57100	2568
+165	3402	10	2.41	0.06	3505	8	60800	1200

Table IV lists the temperature coefficients in machine gun velocity, gage velocity, pressure and action time over the temperature range of -70° to +165° F from the data presented in table III.

It should be noted that all four of the experimental propellants gave temperature coefficients which were much smaller than the standard 20mm ammunition lot KOP-153-18. All propellants were loaded into 20mm ammunition which was primed with the new FAT27E1 electric primer, while the standard ammunition with the WC870 propellant was primed with the M52A3B1 electric primer. Although there are slight differences in the temperature coefficients of the four experimental propellants, it is believed that slight modifications of the FAT27E1 primer to suit each propellant would result in practically the same temperature coefficient with each of these experimental propellants. It should be noted that the short piston velocities recorded at Aberdeen Proving Ground for the lots of cartridges loaded at Frankford Arsenal were all lower than the short piston velocities recorded at Frankford Arsenal at the time of loading.

2. Erosion Tests

The results of the erosion tests with the five lots of ammunition are contained in table V.

The three single base extruded cool burning propellants gave very good uniformity of erosion end point in the tests.

The average erosion life of four barrels with propellant CR7695, Lot 3 (Lot FA-X20.2767) was 2113 rounds. When this type propellant was previously tested for erosion a barrel life of 1723 rounds was obtained. The increase in barrel life may have been due to the lower flame temperature of CR7695, Lot 3. The propellant description sheets (see Appendix) indicate that the two lots of CR7695 had slightly different percentages of methyl centralite coating. The higher percentage of methyl centralite in Lot 3 resulted in about a 60° decrease of the flame temperature.

The other two experimental single base propellants CR7814 (Lot FA-X20-2769) and CR7787 (Lot FA-X20-2768) gave essentially the same average barrel life for four barrels; CR7814 - 2573 rounds and CR7787 - 2558 rounds. All three of the experimental single base propellants developed by Contractor A have approximately the same flame temperature, CR7695 Lot 3 - 2590° K; CR7787 Lot 4 - 2590° K, and

Table IV. Table of Differences of Test Data

(Range from -70° F to +165° F)

		Machine Gun	Gun ₹39	Gage Velocity	ocity		
		Difference Temp.	Temp.	Difference Temp.	Temp.	Pressure	Action
Lot No.	Propellant	f/s	Coef.	8/3	Coet.	psı	
FA-X20-2767	CR7695	. 6	0.41	37	0.16	2600	0.19
FA-X20-2768	CR7787	159	0.68	104	0.44	8400	0.25
FA-X20-2769	CR7814	136	0.58	96	0.40	0099	0.23
FA-X 20-2770	X2048	16	0.39	81	0.34	2900	0.09
KOP153-18	WC870	355	1.51	290	1.23	10900	0.37

Table V. Results of Erosion Tests

Average Disqualification Point	2113 rds	2558 rds	2573 rds	** 4400+ rds	3170 rds
Reason for Disqualification	Excessive velocity loss ditto ditto ditto	Excessive velocity loss ditto ditto ditto	Excessive velocity loss ditto ditto ditto	Test discontinued Barrel still satisfactory Excessive Yaw Test discontinued Barrel still satisfactory	Excessive velocity loss ditto ditto ditto ditto
Disquali- fication Point	1950 rds 2020 rds 2000 rds 2480 rds	2585 rds 2645 rds 2250 rds 2750 rds	2395 rds 2645 rds 2605 rds 2645 rds	6250 rds 1950 rds 5000 rds	2835 rds 3625 rds 3480 rds 2740 rds
Barrel No.	295590 295505 295511 295511	259237 259161 295593 295605	259010 295606 295460 295504	259043 258868 295480	259058 295488 259253 295471
Propellant	CR7695 ditto ditto ditto	GR7787 ditto ditto	CR7814 ditto ditto	X2048 ditto	WC870 ditto ditto
Lot No.	FA-X20-2767 ditto ditto	FA-X20-2768 ditto ditto	FA-X20-2769 ditto ditto ditto	FA-X20=2770 ditto ditto	KOP153-18 ditto ditto ditto

**Average of one disqualified barrel and two barrels in which test was discontinued. *Barrel not disqualified test discontinued because of lack of ammunition.

CR7814 Lot 2 - 2580° K. The longer barrel life obtained with propellants CR7787 and CR7814 may be partially attributable to the fact that the chamber pressure developed with these two propellants is approximately 4000 psi lower than the chamber pressure developed by propellant CR7695.

The experimental double base rolled ball propellant X2048 (Lot FA-X20-2770) was erosion tested in three barrels. Two of these barrels, No. 259043 and No. 295480 were fired 6250 rounds and 5000 rounds respectively and were still serviceable when firing was discontinued due to lack of ammunition. As far as is known these two barrels yielded the longest barrel life attained in M39 erosion testing in the United States. The third barrel, No. 258868, was disqualified because of excessive yaw after 1950 rounds were fired. No cause could be determined for the early failure of this barrel. Dimensionally there appeared to be no significant difference among the three barrels fired and examination of the bore after firing did not reveal any condition to which the failure of Barrel No. 258868 could be attributed. Erosion of the bore surface was light and evidently was not a factor in determining life of this barrel.

The reason that two barrels were not fired to completion because of lack of ammunition with Lot FA-X20-2770, was that originally, in accordance with the established procedure at Aberdeen Proving Ground three barrels were started simultaneously in the erosion test and were fired alternately; that is, a cycle was fired with one barrel and while it was cooling another barrel was fired them a cycle.

When the three barrels had each reached the 1750 round point it was decided to continue firing one barrel at a time because of the limited supply of ammunition. The ammunition was exhausted when barrel No. 259043 had reached the 6250 round point. Then all of the X2048 propellant remaining at Frankford Arsenal was loaded into ammunition resulting in an additional 3500 rounds being sent to Aberdeen Proving Ground. Barrel No. 258868 was fired to disqualification at 1950 rounds and the remaining ammunition was fired in barrel No. 295480 in which the total reached 5000 rounds without disqualification. No more rounds were fired in Barrel No. 259043 because it was believed additional firing would not add to the engineering data.

There were two differences which were probably responsible for the improvement in the erosion characteristics of the rolled X2048

propellant over those observed with WC870 ball propellant. The X2048 propellant has a lower flame temperature than the conventional ball propellant and it does not contain the antifoulant tin-dioxide. Instead of tin-dioxide a cool deterrent was used which contributed to the lower flame temperature. These erosion tests indicated that there were apparently no ill effects caused by the removal of the antifoulant from the X2048 propellant. Smoke, fouling and flash tests will be fired in the final engineering tests.

The average erosion life for four barrels with the control ammunition with propellant WC870 (KOP-153-18) was 3170 rounds. This is considered average for this type of ammunition.

The improvements with respect to erosion with the three new propellants were significant. The rolled ball propellant was superior to the conventional ball propellant WC870 and the new single base extruded propellants (CR7814 and CR7787) were superior to the CR7695 propellant.

CONCLUSIONS

It is concluded that:

- a. With respect to erosion characteristics the new single base extruded cool burning propellants (CR7787 and CR7814) in Gartridge Ball, 20mm, M55 with FAT27E1 primer are greatly superior to IMR7005 propellant and are superior to the previously developed single base cool burning propellant CR7695. Propellants CR7787 and CR7814 apparently meet all the requirements for 20mm aircraft ammunition.
- b. With respect to erosion characteristics the new double base rolled ball propellant X2048, in Cartridge, Ball, 20mm, M55 with FAT FAT27E1 primer is superior to the standard ball propellant WC870. Propellant X2048 apparently meets all the requirements for 20mm aircraft ammuntion.
- c. The new primer FAT27E1 offers a substantial improvement in the ballistic characteristics of 20mm ammunition with respect to high and low temperature firings. Primer FAT27E1 apparently meets all the requirements for 20mm aircraft ammunition.

RECOMMENDATIONS

It is recommended that:

- a. Final engineering and user tests be made with one or both of the single base cool burning extruded propellants CR7787 or CR7814.
- b. Final engineering and user tests be made with rolled ball propellant X2048.
 - c. Final engineering and user tests be made with primer FAT27E1.
- d. Consideration be given to modification of the FAT27E1 primer to suit each individual propellant type prior to final engineering and user tests.

REFERENCES

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- 6. Letter ORDBA-1451 Subject "Ballictic Tests of 20mm Aircraft Ammunition Propellants at A.P.G." dated 11 Oct 1960 to OCO Attn: ORDTS.
- 7. Development and Proof Services, Aberdeen Proving Ground Firing Record No. S-46387.
- 8. Letter Frankford Arsenal to Hill Air Force Base, Attn: OOYES and OOYIT dated 13 July 1961.

APPENDIX

CO FORM 18 Apr. 82 1204		PROPELLANT			ls elle	
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Minimum %		Minhum		_Mine. Min		Nhe.
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Propellant Description Sheet for X2048 and Typical WC870 Propellant

Composition (%)	X-2048	WC870 AL 42747
Nitrocellulose nitrogen	13. 15	a
Nitrocellulose	a	81.01
Nitroglycerin	8.48	8.85
Dibutylphthalate	7.95	6.22
Diphenylamine	0.89	0.86
Dinitrotoluene	0.50	0.73
Potassium nitrate	0.60	0.73
Potassium sulphate	0.42	0
Tin dioxide	0	0.77
Screen Analysis (% Retained)		
Screen Opening		
(in.)		
0.0469	0.1	0.00
0.0394	0.5	0. 00
0.0331	15.0	9. 47
0.0280	46. 3	50. 86
0.0232	37.5	38. 81
0.0197	0. 3	0. 67
0.0165	0.2	0.19
Pan	0.1	0.00
Stability and Physical Tests		
120° C Heat Test (minutes)		
SP	60	65
RF	180+	a
Exp	300+	300+
Form of grain	Rolled	Ball
Web (in.)	0. 020	-
Gravimetric density (gm/cc)	0.942	0.934
Specific Gravity (gm/cc)	1.58	a

aNot reported

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